

Abstract

The development and improvement of commercial hyperspatial sensors in recent years has increased the breadth of information that can be retrieved from spaceborne and airborne imagery. NASA, through its Scientific Data Purchases, has successfully provided such data sets to its user community. A key element to the usefulness of these data are an understanding of the radiometric and spatial response quality of the imagery. This proposal seeks funding to examine the absolute radiometric calibration of the Ikonos sensor operated by Space Imaging and the recently-launched Quickbird sensor from DigitalGlobe. In addition, we propose to evaluate the spatial response of the two sensors. The proposed methods rely on well-understood, ground-based targets that have been used by the University of Arizona for more than a decade.

Introduction

Over the past several years, there has been a dramatic improvement in the spatial and spectral aspects of remote sensing imagers. This has included continued improvements of the AVIRIS sensor with increased signal-to-noise ratio and the upgrades to allow it to fly at low altitudes allowing collections with spatial resolutions as small as 3 m. Other airborne sensors such as Positive System's ADAR are providing better than 1-m spatial data in multispectral bands. The recent addition of the commercial sensors Ikonos and Quickbird has brought 1-m panchromatic data to the non-military user. Previously, high spatial resolution data sets with resolutions better than Ikonos and Quickbird have existed in the military community, but these military-based data are not available to the public (excluding of course the recent release of older Corona Mission photographs). Prior to 2000, the only source of high-spatial resolution data from spaceborne platforms have been archives of older Russian and Indian data sets and low-altitude aircraft data with limited spatial extent and poor geographic availability. Since then, NASA has provided data from several commercial remote sensing enterprises, including Ikonos.

In order for these commercial data sets to be useful to the NASA community, it is critical to understand the behavior of the sensors needed to provide these data. This work proposes to evaluate the radiometric and spatial characteristics of the Ikonos and Quickbird sensors.

Science Plan

The work proposed here to evaluate the radiometric accuracy of Ikonos and QuickBird includes defining data collections needed to perform a radiometric assessment (including tasking requirements such as locations and collection times), collecting the appropriate data sets, processing these data, and supplying results to NASA via a presentation at the High Resolution Commercial Imagery Workshop as well as any required reports. The proposed radiometric work will consist of up to three Ikonos datasets to be acquired preferably between June and December 2002 and up to five QuickBird acquisitions during the same period. The number of desired images are to allow an adequate understanding of the radiometric behavior of the sensors, but it should be understood that poor weather at the time of acquisition or other factors such as sensor malfunction could further limit the number of collections that are available. In the case of fewer available images, other options such as cross-comparison to other systems will be used to ensure the validity of any conclusions drawn. The acquisitions must occur when members of the RSG are present at the test site since the

radiometric characterization will rely on the so-called reflectance-based approach. This method uses ground truth data collections coincident with the functional data acquisition collects as part of a method to predict at-sensor radiance.

The sites that will be used for this proposed work are White Sands Missile Range, Ivanpah Playa, Railroad Valley Playa, and Lunar Lake Playa. The areas are relatively absent of vegetation and have fairly flat spectral reflectance that is quite high in the visible and near infrared. The level of reflectance varies with season with the lowest reflectance values during the winter months. Highest reflectance values are typically seen in late fall after the surfaces have dried after summer-season rains. White Sands is the largest of the test sites with Railroad Valley the largest of the playa test sites. The playa test sites have lower reflectance than White Sands in all bands of this work and will have much lower reflectance in the blue relative to other bands. Lunar Lake is the most spatially uniform of the test sites and is also at the highest elevation (more than 1.8 km).

The proposed method for this work, the reflectance-based approach, relies on ground-based surface reflectance measurements of a selected target at the time of sensor overpass. The surface reflectance of a small area of the site is found by comparing radiometer measurements of the site to those from a diffusely reflecting panel of known reflectance calibrated at RSG facilities. The spectroradiometer, is transported across the entire site, and measures the upwelling across the spectral range between 350 and 2500 nm. The area that will be used for both Ikonos and QuickBird is 300 by 80 m and is subdivided into 20 m by 20 m areas within which 8 spectral samples are collected. All samples are averaged to give a single reflectance value and this area is compared to that in the satellite imagery. Solar radiometer data are used in a Langley method retrieval scheme to determine spectral-atmospheric optical depths. The optical depth results are used as part of an inversion scheme developed by the RSG to determine ozone optical depth and a Junge aerosol size distribution parameter. Columnar water vapor is derived using a modified Langley approach and this retrieved columnar water vapor is used as an input to MODTRAN3 to determine transmittance for the sun-to-surface-to-satellite path.

The results of the field measurements serve as input to a Gauss-Seidel iteration radiative transfer code to predict the top-of-the-atmosphere radiance. The hyperspectral output from the code is band-averaged using the respective spectral response data to determine the band-averaged, at-sensor radiance for the test site at the time of the satellite data collection. These radiances are compared to average digital numbers analyzed from the imagery of the selected site to determine the radiometric calibration of the sensor.

The assessment of the spatial response of the Ikonos and QuickBird sensors will be accomplished with some acquisitions of special targets that must be deployed for the collects and with some acquisitions that require only cloud-free coverage of the target area. The work proposed here to evaluate the spatial characteristics of Ikonos and QuickBird includes defining data collections needed to perform a spatial assessment (including tasking requirements such as locations and collection times), collecting the appropriate data sets, processing these data, and supplying results to NASA via a presentation at the High Resolution Commercial Imagery Workshop as well as any required

reports. The proposed spatial work will consist of one Ikonos dataset and up to three QuickBird acquisitions. The number of desired QuickBird images is to allow an adequate understanding of the spatial behavior of the sensor, but it should be understood that poor weather at the time of acquisition or other factors such as sensor malfunction could further limit the number of collections that are available. In the case of fewer available images, other options such as cross-comparison to other systems will be used to ensure the validity of any conclusions drawn. In the unfortunate case that the single Ikonos collection is not available, further work on historical data sets will be performed to refine past estimates of spatial response. The single Ikonos collect is desired near mid-July 2002 to provide near-anniversary coverage with the July 23, 2000, and July 15, 2001, collects of Tucson. A relative image sharpness comparison will be performed on the set of 3 images to assess any changes in Ikonos performance over the 3 year period. One Quickbird collect near the same date is desired to allow direct Ikonos-Quickbird comparison of spatial performance. The remaining two Quickbird collects are desired in early Fall 2002 to minimize probability of cloud cover in the Tucson area.. The acquisitions must occur, however, early enough to allow timely presentation of the results in the March 2003 timeframe. The primary test site for the spatial calibration work will be the Tucson metropolitan area. Several sites have been used in the past for similar work, but the most likely site that will be used is located at the Pima County Fairgrounds. This area has the advantage of also being used by the University of Arizona for radiometric calibration work and would offer additional opportunities to assess radiometric accuracy at the same time as spatial response.

The method that will be used for the spatial analysis of both sensors is similar to that used in the past for Ikonos. The approach relies on imaging targets of known spatial contrast and applying Fourier Transform methods to infer the Modulation Transfer Function of the sensor from these data. The ideal case is an array of point sources placed in a well-characterized grid. Due to the difficult nature of developing point sources, the work here will use white rectangular targets that will be placed on a dark background area. The relatively small size of the white targets allows them to be treated essentially as point sources, to a degree, and the use of a grid of these targets provides the information necessary to infer the spatial response characteristics of the sensors.

Recent work has also found that several evenly spaced line targets exist at the Fairgrounds test site (parking lot stripes) and these can be used to simulate line sources that can then be used in a similar fashion as the "point" targets to assess the spatial performance. The final approach for spatial assessment is to use well-understood edge targets rather than the line targets. The advantage to the edge target approach is that there are a larger number of possible areas within the scene with which this approach can be applied.

Work plan

The field work described above will take place during the summer and fall of 2002. Preliminary acquisition plans will be developed in early June to allow for maximum coordination with the Stennis Space Center plans for field work. There is a desire to collect at least one radiometric data set each for Ikonos and QuickBird at a selected site in the November/December timeframe to make use of the lower sun angle and thus lower at-sensor radiance levels. The White Sands data set would

be collected in either the June or September timeframe to make use of the high sun angle and lower probability of clouds. The spatial analysis work would preferentially occur in the fall, but all acquisitions (including radiometric) should occur as to allow delivery of the imagery data through the Scientific Data Purchase by December 2002. In all cases, the PI and CO-I will coordinate closely with NASA SSC's TTSC support contractor for the scheduling of Ikonos and QuickBird-2 acquisitions

Once the field data are collected and analyzed, the results will be evaluated to determine the quality of the Ikonos and QuickBird data sets. The results of the quality assessment will be forwarded to Stennis Space Center in preliminary form in February 2003, presented at the High Spatial Resolution Commercial Imagery Workshop in March 2003, and in a final report submitted at the end of the project. In addition, the work that has been done in the past with Ikonos and the proposed work will be presented at the November ISPRS meeting. This presentation will use the results of the past and proposed work to give an overview of the current knowledge of terrestrially-based radiometric calibration approaches and proposed methods to make such approaches more uniform across platforms spanning hyperspatial to hyperspectral.

As part of this work, we propose the following list of deliverables

- 1) An interim written report documenting the status of the radiometric characterization to be delivered on or by 15 October 2002.
- 2) An interim written report documenting the status of the spatial characterization to be delivered on or by 15 October 2002. (1 and 2 may be combined as a single report.)
- 3) Preliminary results of radiometric assessments via email by 15 February 2003.
- 4) Provide preliminary results of spatial assessments via email by 15 February 2003.
- 5) An oral presentation, associated viewgraphs, and proceedings paper documenting methods for pre-flight and in-flight radiometric calibration/characterization presented at the ISPRS Commission I Symposium to be held in Denver, CO to be delivered by 30 November 2002.
- 6) An oral presentation and associated viewgraphs documenting the radiometric characterization presented at the High Spatial Resolution Commercial Imagery Workshop tentatively scheduled to be held in the Washington D.C. area in March 2003. The deliverables must be delivered by the date of the workshop.
- 7) An oral presentation and associated viewgraphs documenting the spatial characterization presented at the High Spatial Resolution Commercial Imagery Workshop tentatively scheduled to be held in the Washington D.C. area in March 2002. The deliverables must be delivered by the date of the workshop.
- 8) A final written report documenting the performed radiometric characterization to be delivered on or by 31 May 2003.
- 9) A final written report documenting the performed spatial characterization to be delivered on or by 31 May 2003. (8 and 9 may be combined as a single report.)

Personnel

The PI, K. Thome is an Associate Professor in the Optical Sciences Center and will be the lead investigator on the radiometric calibration portions of this work. Co-I, R. Schowengerdt is a Professor in the Electrical and Computer Engineering Department and will be the lead investigator on the spatial assessment part of the work. Other personnel on this project will be a postdoctoral employee to assist Thome in planning and implementing the field campaigns for the radiometric characterization, processing of the field data, and analyzing and presenting the results relative to the output of Ikonos and QuickBird. A graduate associate in the ECE Department will be used to assist with the deployment of the spatial analysis targets and processing of the data for this work.

Proposed Costs

Funding requested for the proposed work is primarily for personnel costs and for a field experiments to the remote test sites in Nevada and New Mexico. Funding is requested for roughly three weeks of Thome's time to analyze results of the work and present these results. Because of strong overlap with other projects funded by NASA, a portion of Thome's participation in field activities and his time at the ISPRS conference will be supported by these projects. Funding is requested for 5% of Schowengerdt's time during the academic year and 1 ½ weeks of summer funding to collect, analyze, and present the results of the spatial portion of the proposal. The bulk of the processing and data analysis for the radiometric portion of the proposed work will be done by funding a postdoctoral employee at approximately ½ time. In addition, 1/4 time for a graduate assistant during the academic year and 160 hours of graduate student time is requested to assist Schowengerdt with collection and analysis of the spatial analysis work, and technician and graduate student time is requested to assist Thome in collection of the field data sets.

Travel costs include funding for six field campaigns to Nevada and New Mexico with two people per two day trip. In the past, much of the field work could be subsidized through joint activities with other sensors. It is still hoped that this can occur for two of the campaigns, but the known idiosyncracies of the QuickBird orbit may limit joint campaign opportunities. Additional travel is requested as well to support four people, Schowengerdt, Thome, and the postdoctoral employee and student for attendance at the High Spatial Resolution Imagery Workshop, for Thome and Schowengerdt to present preliminary results at Stennis Space Center, and for Thome to present a summary of current methods in radiometric calibration at the ISPRS meeting in November in Denver. The budget is detailed below.